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REMARKS

Claims 1 and 3 are pending in this application. Claims 1 and 3 have been amended to further distinguish over the prior art references. The specification has been amended to correct typographical errors. Support for amendments of claims 1 and 3 can be found in Example 4 of Table 3 in the specification as originally filed. No new matter has been added.

Claims 1 and 3 stand rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 6,053,991 to Yokoi et al. (hereinafter "Yokoi"), or U.S. Patent No. 2,905,577 to Harris et al. (hereinafter "Harris"), or U.S. Patent No. 5,779,821 to Ishii et al. (hereinafter "Ishii").

The present invention is directed to a steel that has excellent abrasion resistance. The steel consists essentially of 8.0-35.0 wt.% Cr, 0.05-0.65 wt.% C, 0.05-3.0 wt.% at least one of Ti, Nb, Zr, V and W, the balance being essentially Fe. The steel structure has a total amount of Ti, Nb, Zr, V and/or W carbide precipitates distributed in a steel matrix adjusted to 0.1 wt.% or more.

The present invention is also directed to an abrasion-resistant steel consisting essentially of 8.0 to 35.0 wt.% Cr, 0.05 to 0.65 wt.% C, and at least one of 0.05 to 1 wt.% Ti and 0.05 to 1.50 wt.% Nb wherein an aggregate of Ti + Nb is 0.50 to 2.0 wt.%, with the balance being essential Fe. Optionally the steel includes one or more metals selected from the group consisting of Zr, Al and W in an aggregate summed with Ti + Nb up to 3.0 wt.%, as well as optionally one or more of 0.2-5.0 wt.% Ni, 0.1-3.0 wt.% Mo and 0.2-3.0 wt.% Cu. The steel structure has a total amount of Ti, Nb, Zr, V and/or W carbide precipitates distributed within a steel matrix in an amount of at least 0.1 wt.%.

The Yokoi patent discloses the production of a cold working tool steel with improved fatigue strength and thus has wear resistance and tensile compression fatigue strength. The Ishii patent discloses a rotor for a steam turbine made of a heat-resistant steel with excellent high temperature strength. The Harris patent discloses a ferritic chromium steel with improved creep resistance.

In view of the above amendments and in light of the arguments below, Applicants respectfully disagree with the Examiner's assertion that Yokoi, Harris, or Ishii teach or suggest specific abrasion resistant steel alloys which meet the composition in amended independent claims 1 and 3. Amended independent claims 1 and 3 require a carbon content of .05-0.65 wt.%. Such a lower C content, for example, suppresses the unfavorable precipitation of large eutectic Cr carbide. Yokoi teaches away from a carbon content lower than 0.65 wt.%. In particular, column 4, lines 23-28 of Yokoi discloses that "when the carbon content is less than 0.65%, the secondary hardening hardness is unsatisfactory", and carbon content "is more preferably in the range of 0.75-1.1%" to achieve balance between the strength and the toughness of the steel. Therefore, Yokoi teaches away from the steel composition in amended independent claims 1 and 3.

Additionally, Yokoi does not teach or suggest a steel having a structure with a total amount of Ti, Nb, Zr, V and/or W carbide precipitate, distributed in a steel matrix to 0.1 wt.% or more as in amended independent claims 1 and 3. Applicants respectfully disagree with the Examiner's assertion that such a structure would be inherent because the compositional limitations are met and Yokoi teaches the presence of 1-9% M_7C_3 to improve abrasion resistance. As discussed above, Yokoi does not teach or suggest the steel composition in amended independent claims 1 and 3, specifically a lower C content of 0.05-0.65 wt.%. Moreover, Yokoi is directed to a tool steel which achieves abrasion resistance and fatigue strength by controlling the grain diameter of carbides and the percentage area of

M₇C₃ type carbides as disclosed in col. 3 lines 3-8. For example, the particle size, i.e. grain diameter, of M₇C₃ carbides is controlled to 5-15 μm and the surface ratio or percentage area is controlled to 1-9%. While Yokoi discloses the precipitation of M₇C₃ carbides at a surface ratio of 1-9%, it does not teach or suggest Ti, Nb, Zr, V and/or W carbide precipitates of 0.1 wt.% or more. Thus, a surface ratio or concentration of carbides on a surface of steel disclosed in Yokoi does not teach or suggest a wt % of carbides present in a steel matrix as in amended independent claims 1 and 3.

Additionally, metal carbides are not always precipitated as M₇C₃. For example, Nb and V are not precipitated as M₇C₃, but rather as MC and M₄C₃ carbides, respectfully. Yokoi teaches the precipitation of Cr carbides for the improvement of abrasion resistance, with V and Nb carbides as secondary hardeners and does not teach or suggest a steel matrix of Ti, Nb, Zr, V and/or W carbides for abrasion resistance having at least 0.1 wt.% as in amended independent claims 1 and 3. Yokoi only discloses a surface ratio of M₇C₃ present and wt.% of the elements Mo, W, V, Nb individually in Table 1. There is no motivation to require at least 0.1 wt.% carbides of Ti, Nb, Zr, V, and/or W in Yokoi for abrasion resistance in steel as in amended independent claim 1 and 3..

Additionally, Yokoi does not teach or suggest the addition of at least one of 0.05-1 wt.% Ti and 0.05-1.50 wt.% Nb with an aggregate of Ti and Nb of 0.50-2.0 wt.% to the steel as in amended independent claim 3. For all of the foregoing reasons, reconsideration of the rejections of amended independent claims 1 and 3 in view of Yokoi is respectfully requested.

Harris does not teach or suggest a steel excellent in abrasion resistance having a structure with a total amount of Ti, Nb, Zr, V and/or W carbide precipitates distributed to 0.1 wt.% or more as in amended independent claims 1 and 3. Harris is directed to a ferritic chromium steel, which achieves improved creep rupture strength by solution or precipitation

hardening. Harris, however, fails to teach or suggest precipitates of Ti, Nb, Zr, V and/or W carbides and fails to teach or suggest generating 0.1 wt.% or more of such precipitates. The precipitates described by Harris exist at a high temperature, act as inhibitors against the motion of dislocation and are effective for improvement of creep rupture strength. Such precipitates will be uniformly distributed as fine particles for improvement of creep rupture strength. However, precipitates formed for improved abrasion resistance in amended independent claims 1 and 3 are hard particles of relatively large size.

Furthermore, the precipitates in Harris are formed by aging at a temperature of 700°C or lower after solution-treating. According to Harris, steel is aged at a temperature of 700°C or lower after solution-treatment, so as to disperse fine precipitates. On the other hand, the present invention does not require additional processing such as an aging treatment to form carbides or require additional processing to disperse fine precipitates in order to achieve abrasion resistance. The fine precipitate dispersion is necessary for creep resistance in Harris and not for abrasion resistance as in the present invention. The carbides in the present invention are precipitated during solidification or cooling and are not controlled to be fine precipitates. The difference in heat treatment for generation of precipitates between Harris and the present invention results in different kinds and amounts of precipitates. Accordingly, the steel of Harris does not inherently contain 0.1 wt.% of carbide precipitates of Ti, Nb, Zr, V and/or W.

In addition, the present invention aims at improvement of abrasion or wear resistance, but not creep resistance. Since wear resistance of steel significantly depends on hardness of precipitates, carbides of Ti, Nb, V, Zr or W are dispersed in a steel matrix at a predetermined ratio in order to obtain abrasion resistant steel that is superior to conventional steel including chromium carbide as a hardening agent. Precipitation of hard carbides without the use of thermal treatments clearly distinguishes the present invention from Harris.

Reconsideration of the rejections of amended independent claims 1 and 3 in view of Harris is respectfully requested.

Ishii does not teach or suggest a steel with abrasion resistance having a structure with a total amount of Ti, Nb, Zr, V and/or W carbide precipitates distributed to 0.1 wt.% or more as in amended independent claims 1 and 3. Ishii is directed to a steam turbine rotor with improved creep rupture strength obtained in a similar manner with grain size control and heat treatments as discussed hereinabove in connection with Harris. As disclosed in col. 7 lines 15-34 of Ishii, it is the control of the precipitate grain size that improves the creep strength in the steel. Additionally, Ishii discloses that the heat resistant steels achieve greatly improved creep resistant after they are exposed to high temperatures for many hours. This creep strength is achieved in Ishii by controlling grain size and thermal treatment. The present invention rather achieves improved abrasion resistance by control of the types of carbides, Ti, Nb, Zr, V and/or W and the amount of such carbide precipitates, at least 0.1 wt.%, without any thermal and or aging treatments.

Furthermore, Ishii fails to teach a steel composition with at least one of 0.05-1.0 wt.% Ti and 0.05-1.50 wt.% Nb, wherein an aggregate of Ti + Nb is 0.50-2.0 wt.%. For the foregoing reasons and the reasons discussed hereinabove in connection with Harris, reconsideration of the rejections of amended independent claims 1 and 3 in view of Ishii is respectfully requested.

Furthermore, the Applicants respectfully disagree with the Examiner's assertion that having 0.1 wt.% or more carbides amount to no more than routine optimization. Applicants have selected the use of Ti, Nb, Zr, V and/or W carbides to increase abrasion resistance of steels because these carbides have a hardness nearly equal to hard particles such as alumina and silicon carbide. Moreover, as disclosed on page 4, line 22 - page 5, line 7 of the specification and in Fig. 1, when a sufficient amount of Ti, Nb, Zr, V

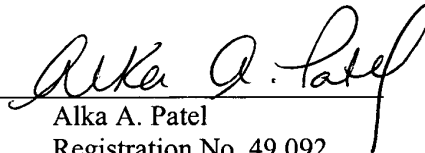
and/or W carbide precipitates are distributed in the steel matrix, abrasive abrasion is suppressed. Fig. 1 illustrates the comparison of the suppression of abrasive abrasion of the steel of the present invention with other steel members having the same hardness but not having the requisite carbide precipitates. Therefore, the amount of carbide precipitates as in amended claims 1 and 3 is not mere routine optimization, but is rather critical with regard to the types and combinations of carbide precipitates formed as discussed hereinabove.

CONCLUSION

In view of the foregoing amendments and remarks, claims 1 and 3 are deemed to be in condition for allowance. Reconsideration of the Examiner's rejections and allowance of pending claims 1 and 3 are respectfully requested.

Respectfully submitted,

WEBB ZIESENHEIM LOGSDON
ORKIN & HANSON P.C.

By 
Alka A. Patel

Registration No. 49,092
Attorney for Applicants
700 Koppers Building
436 Seventh Avenue
Pittsburgh, PA 15219-1818
Telephone: (412) 471-8815
Facsimile (412) 471-4094